Air is a Fluid

Session Time: Two, 50-minute sessions

DESIRED RESULTS

ESSENTIAL UNDERSTANDINGS

The principles of aerodynamics allow an aircraft to fly, yet those same principles limit its ultimate performance and capabilities. (EU2)

Safe and efficient aviation operations require that pilots use math, science, and technology. (EU4)

ESSENTIAL QUESTIONS

1. Why does it matter that air behaves like a fluid?

LEARNING GOALS

Students Will Know

- Air is a gas that behaves like a fluid
- How movement is impacted by viscosity and friction
- Principles of the Coanda Effect and the Magnus Effect

Students Will Be Able To

- *Explain* why air is considered a fluid. (DOK-L2)
- *Analyze* how the movement of a fluid is affected by viscosity and friction. (DOK-L4)
- *Explain* how the Coanda Effect and Magnus Effect influence the flow of air around objects in motion. (DOK-L3)

ASSESSMENT EVIDENCE

Warm-up
Students create a graphic organizer comparing general properties of friction and those specific to fluids. They fill out their understanding of the general properties of friction as a warm-up and later write down properties of friction specific to fluids.

Formative Assessment
Students explain how the Coanda Effect and the Magnus Effect work, as well as similarities and differences between the Coanda Effect and Magnus Effect.

Summative Assessment
Students explain the Magnus Effect and use it to describe the phenomenon shown in a video.

LESSON PREPARATION

MATERIALS/RESOURCES

- Air Is A Fluid Presentation
- Air Is A Fluid Student Activity 1
- Air Is A Fluid Student Activity 2
- Air Is A Fluid Teacher Notes 2
- Air Is A Fluid Teaching Aid

Honey Demonstration (per class)

- Two jars of honey
- One or 2 large bowls

Viscosity Activity (per group)

- 1 marker
- 1 basin to catch fluids; the basin should be wide enough to hold the incline
- Vertical support for incline (such as a stack of books or a clamp and stand)
- 1 stopwatch
- 3 different inclines, each approximately 15 cm wide x 50 cm long
  - One of the inclines should have a smooth surface, such as glass
  - One incline should mimic the smooth aluminum metal of airplanes (e.g. a sheet of aluminum from a hardware store)
  - Other materials to consider include wood, sandpaper, aluminum foil, Velcro, or plastic wrap
- 4 different fluids for students to test (e.g. water, glue, syrup, oil)
- 4 100 ml beakers (or other small containers such as paper or plastic cups)

The Coanda Effect and Magnus Effect Activity (per student)

- Strip of paper approximately 5 cm x 25 cm. The paper should not be too flimsy, as it needs to hold a convex shape.
- Two paper, plastic, or foam cups
- Tape or glue
- Four long rubber bands

LESSON SUMMARY

Lesson 1: Air is a Fluid

Lesson 2: Air Density

In this lesson, students will explore the classification of air as a fluid. A fluid is a substance, typically a gas or liquid, that does not have a set shape and yields to external pressure so that it flows around objects moving through it. Although water is denser than air, an airfoil's movement through the air is not dissimilar to a boat's motion through water.

To begin, students will reflect on what they already know about how friction acts on solid objects and note these properties on a graphic organizer. They will then explore the viscous properties of fluids (their tendency to resist deformation) by predicting and observing the flow of fluids down inclines of different materials.

During the next part of the lesson, students will observe examples of the Coanda Effect and Magnus Effect. Using these examples, they will learn how these phenomena affect the movement of objects through a fluid.

Finally, students will use their understanding of the Magnus Effect to explain the movement of a model aircraft in a video.

BACKGROUND

In this lesson, students will explore the properties of air that make it a fluid. In particular, they will explore how friction is related to viscosity. Viscosity is the resistance or opposition to flow; it is the opposite of fluidity. Viscosity can be thought of as "fluid friction." Note that students will apply these concepts to airfoils in a later unit.

The Coanda and Magnus effects are related to the fluidity of air. The Coanda Effect is the tendency of a jet of fluid (in this case air) to attach to a convex surface (a surface that bulges outward). A jet of air is surrounded by a sleeve of low pressure. If a convex surface is placed near a jet of fluid, a region of low pressure occurs on that side of the jet. This causes a pressure imbalance where the jet is pulled toward the convex surface and adheres or “sticks” to it. The forces created by the Coanda Effect can cause lift under certain circumstances.

The Magnus Effect occurs when a spinning object drags a fluid (in this case, air) faster along one side of the object than the other. On one side, the air dragged with the object collides with the passing airstream. This causes the airstream to decelerate, setting up an area of high pressure. On the opposite side of the object, the air is moving in the same direction as the airstream. This speeds the airstream up, which creates an area of low pressure. The difference in pressure between the two sides creates a force which moves the object in the direction of low pressure. The Magnus Effect is most often seen in sports, when players add spin to a ball to change the direction or range of motion (e.g. a baseball or a golf ball).

DIFFERENTIATION

Struggling students may need a refresher on the difference between gases, liquids, and solids at the particle level, during the **EXPLORE** section. Encourage students to research the similarities and differences among gases, liquids, and solids by creating a Venn diagram. To support student comprehension in the **EXPLAIN** section, have students draw models of air flow in the Coanda Effect and Magnus Effect. After students have created their visual models, pair students and have them explain how the Coanda Effect and Magnus Effect are different. Encourage pairs to think of real-world examples where each phenomenon occurs.

LEARNING PLAN

ENGAGE

Teacher Material: Air Is a Fluid Presentation

Slides 1-3: Introduce the topic and learning objectives of the lesson.

Slide 4: Conduct the **Warm-Up**.

Warm-Up

To review what students know about friction, have students work individually to create a 2-column graphic organizer with the left column titled “General Properties of Friction” and the right column titled “Friction and Fluids.” In the “General Properties of Friction” column, have students write 3-5 facts about friction. Allow for a brief discussion when they are finished.

Possible student responses include: friction slows down moving objects, friction is greater on rough surfaces, friction opposes the direction of motion, friction creates heat, friction is greater on stopped objects than moving objects, etc.

Note: Students will later expand the “Friction and Fluids” column of their graphic organizers to include information about how friction applies to fluids.

[DOK-L1; *describe*]

EXPLORE

Teacher Materials: Air Is a Fluid Presentation, Air is a Fluid Teaching Aid
Student Material: Air is a Fluid Student Activity 1

Slide 5: Begin this section by introducing students to the idea of fluid flow and viscosity. Bring two jars of honey to class. Refrigerate one for several hours before class and keep one at room temperature. Then, ask a student to pour both jars into a bowl. Explain that honey flows differently at different temperatures because of a physical property known as viscosity. Physical properties are observable characteristics of substances that can be measured without changing the substance.

Slide 6: Refer to **Air is a Fluid Teaching Aid** for details on the viscosity demonstration. This demonstration will provide students the opportunity to investigate variables that affect the movement of fluids over surfaces, similar to the movement of air over wings. Begin the demonstration as an entire class. Set up the demonstration outlined in steps 1-3 of the A**ir is a Fluid Student Activity 1.** Instruct students to fill in the table in step 2 of the activity sheet by making predictions about how each fluid will flow down the incline. Assign a student to time each liquid as it flows down the incline. Discuss student observations as a class and have them document their observations on the activity sheet.

Then divide the class into groups of 4 to 6 students, and have each group complete the remaining steps of the Viscosity Activity in **Air is a Fluid Student Activity 1** starting with step 4. After students have completed the activity, have each group share their conclusions with the class. Which fluid flowed fastest over which material?

Explain to students that interactions between molecules can slow down the movement of fluids. Fluids that are the most viscous have strong intermolecular bonds, which slow their movement. As they are flowing down the surface, bonds between the fluid and the surface will also slow down movement. Rougher surfaces have more area with which to form bonds, thereby slowing movement further.

Slide 7: Explain to students that air is a fluid just like the fluids they just investigated in the Viscosity Activity, but air has a much lower viscosity than those fluids.

- “Gases Are Fluids” (Length 2:49)
  http://video.link/w/suUd

Questions

Using what they learn in the video, ask students, as a class, to summarize why air is a fluid.

Possible Answers: The scientist was able to pour a gas out of a flask. Like liquids, gases flow and do not maintain a constant shape. Therefore, they are fluids.

EXPLAIN

Teacher Material: Air Is a Fluid Presentation, Air Is A Fluid Teacher Notes 2
Student Material: Air is a Fluid Student Activity 2

Slide 8: Motivate the remaining discussion in this lesson by asking students to consider the consequences of air being a fluid. If air is a fluid, this means that airplanes move through fluids. Therefore, to study the movement of airplanes through the air, we have to understand how objects move through fluids. Two properties that affect the movement of objects through fluids are the viscosity of the fluid and the friction between the object and the fluid.

Slides 9-10: Explain viscosity and friction to students. Define viscosity as the resistance of a fluid to a change in shape or a change in its motion. Show the "What is Viscosity" video to reinforce this definition. Then review what friction is with a quick popcorn strategy where students call out what they already know about friction. Then show slide 10 to define friction as the resistance in motion between surfaces. Finally, show students the video about fluid friction. Ask students to compare the differences between fluid friction and friction between solids.

- "What is Viscosity" (Length 1:03)
  http://video.link/w/tuUd

- "What is Fluid Friction" (Length 4:16)
  http://video.link/w/uuUd

Slide 11: Begin session 2 by describing the Coanda Effect. The Coanda Effect is the tendency of a jet of fluid (in this case air) to attach to a convex surface. A jet of air is surrounded by a sleeve of low pressure. If a convex surface (a surface that bulges outward) is placed near a jet of fluid, a region of low pressure occurs on that side of the jet. This causes a pressure imbalance where the jet is pulled toward the convex surface and adheres or "sticks" to it. The forces created by the Coanda Effect can cause lift under certain circumstances.

After explaining the Coanda Effect, have students watch the video to observe this effect. Then ask students whether they can think of examples of this effect in their everyday life. Examples would include fans (especially "jet fans"), computer chip cooling fans, Coanda vacuum cleaners, building ventilation systems, and jet boats.

- "The Coanda Effect" (Length 3:05)
  http://video.link/w/j8Xd

Slide 12: The Magnus Effect occurs because a spinning object drags the air around it. The air being dragged by the object interacts with the surrounding air to create regions of high and low pressure. If the region of low pressure is imbalanced, the object is pulled toward the region of lowest pressure. This allows baseball pitchers or soccer players to curve the path of their balls by varying the amount of spin they put on the balls. Have students watch the video to observe this effect. Explain that the Magnus Effect can also affect the trajectory of flying projectiles, such as spinning missiles.

- "Curve Ball" (Length 3:23)
  http://video.link/w/MaYd

Have students complete **Air is a Fluid Student Activity 2** to demonstrate the Coanda and Magnus Effects. Answers can be found in **Air is a Fluid Teacher Notes 2.**

Slide 13: Conduct the **Formative Assessment**.

Formative Assessment

Have students individually write their answers to the three questions on slide 13. Students should use their observations from the **Air is a Fluid Student Activity 2** in their explanations.

How does the experiment with the strip of paper demonstrate the Coanda Effect?

Possible Answer: The Coanda Effect occurs when a jet of air moves across a convex surface. In this case, a jet of air is blown from the mouth. Because the paper droops downwards, it is a convex surface. The strip of paper moves towards the jet of air.

How does the experiment with the flying cups demonstrate the Magnus Effect?

Possible Answer: The flying cups are spinning objects that drag air molecules around them when they spin. This creates areas of low pressure around the cup, pulling the cup in different directions. This accounts for the path of the cups through the air.

What are the similarities and differences between the Coanda Effect and the Magnus Effect?

Possible Answer: The Coanda Effect and the Magnus Effect both arise from moving air molecules creating areas of high and low pressure. The Coanda Effect describes the tendency for a jet of fluid to attach to a convex surface. The Magnus effect describes the movement of spinning objects toward an area of low pressure located perpendicular to the axis of spin.

[DOK-L3; *compare*, DOK-L2; *interpret*]

EXTEND

Teacher Material: [Air Is a Fluid Presentation]

Slide 14: After students have completed demonstrations of viscosity, the Coanda Effect, and the Magnus Effect, have them fill in the "What I know about friction and fluids" column of the graphic organizer that they began in the warm-up. Some things they have learned about friction and fluids include: fluids move more slowly as viscosity is increased, fluids move more slowly when they interact with rough surfaces, moving fluids can stick to objects through the Coanda Effect, moving fluids create regions of low pressure, spinning objects can create life because of the Magnus Effect, etc.

EVALUATE

Teacher Material: [Air Is a Fluid Presentation]

Slide 15: In this summary slide, remind students that air is a fluid just like water, and its behavior is very similar. In many ways, the movement of airfoils through air is similar to the movement of boats through water. Tell students that the behavior of air and other fluids will impact the designs of airfoils, which they will study later.

Slide 16: Conduct the **Summative Assessment.**

Summative Assessment

Ask students to watch "Amazing Magnus Effect RC Plane" (Length 6:35).

- http://video.link/w/k8Xd

After the video, have students draw a diagram of the aircraft showing regions of high and low pressure while in flight. Also have students write a brief paragraph explaining how the Magnus Effect is demonstrated during flight.

[DOK-L3; *explain*]

Summative Assessment Scoring Rubric

- Follows assignment instructions
- Student work shows:
  - An understanding of how spinning objects create areas of low pressure.
  - An understanding of how the Magnus Effect is used during the flight of the aircraft.
- Contributions show understanding of course of the concepts covered in the lesson
- Contributions show in-depth thinking including analysis or synthesis of lesson objectives

Points **Performance Levels**

9-10 The diagram clearly shows that the area of high air pressure is below the rotor and the low air pressure is above. The paragraph clearly explains the Magnus Effect, in which the aircraft is drawn toward the area of lower pressure keeping the aircraft above ground.

7-8 The diagram shows areas of high and low air pressure and the paragraph explains the Magnus Effect. Minor gaps in understanding are evident.

5-6 A good attempt, but the diagram and the paragraph show very little knowledge of air pressure and the Magnus Effect.

0-4 Both the diagram and paragraph show little or no understanding of air pressure and the Magnus Effect. Student work is sloppy and difficult to follow.

STANDARDS ALIGNMENT

NGSS STANDARDS

Three-dimensional Learning

- **HS-PS3-2** - Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative position of particles (objects)
  - Science and Engineering Practices
    - Developing and Using Models
    - Planning and Carrying Out Investigations
  - Disciplinary Core Ideas
    - PS3.A Definitions of Energy
  - Crosscutting Concepts
    - Energy and Matte

COMMON CORE STATE STANDARDS

- **RST.9-10.7** - Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.

- **WHST.9-10.1** - Write arguments focused on discipline-specific content.

- **WHST.9-10.8** - Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the usefulness of each source in answering the research question; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and following a standard format for citation.

- **WHST.9-12.9** - Draw evidence from informational texts to support analysis, reflection, and research.

REFERENCES

https://www.karmak.org/archive/2003/02/coanda_effect.html
http://www.discoverhover.org/infoinstructors/guide8.htm
http://thekidshouldseethis.com/post/demonstrations-of-the-coanda-effect
https://interestingengineering.com/magnus-effect-physics-behind-bending-it-like-beckham
https://www.freedawn.co.uk/scientia/2015/07/23/what-is-the-magnus-effect-and-how-does-it-work/